Abstract

In MEMS applications, less loading on rectangular micro cantilever beam surface gives negligible deflection at its free end and poor sensitivity. In this paper, three new micro cantilever designs are presented, which hold promises for better deflection and higher sensitivity. The proposed designs provide the free end deflection nearly twice as the conventional rectangular beam. The work is carried out by using COMSOL Multiphysics software to analyze the deflection of the proposed cantilever designs. Further study is carried out by using piezoelectric material on the surface of cantilever beams for better comparisons and best results.

1. Introduction

Micro electro mechanical system incorporates highly sensitive miniaturized devices such as sensor and actuator which have high throughput, high performance, low cost and easy fabrication. These miniaturized devices are widely used in various sensing and switching applications. Mainly three type of bio-sensing transduction method are used: Potentiometric, Amperometric and micro cantilever biosensor. In potentiometric biosensor, the detection of bio-molecules is achieved by the measurement of change in current value from source unit to drain unit. This method is limited to
only the detection of charge molecules like DNA. In amperometric biosensor, electrodes are used for bio-molecular detection. This method of bio-sensing is also limited to charge molecules. The facility of multi agent detection is not feasible in both these bio-sensing method. In micro cantilever based biosensor, the concentration of bio-molecules present at the cantilever surface can be achieved by the stress generated inside the cantilever or by the frequency difference. MEMS cantilevers for bio sensing, are adequate to convert bio-molecular event into specific measurable quantity.

MEMS cantilever gives quick and exact response based on bio-molecular activities as compare to the conventional cantilever design. The small size and less amount of analyte required in detection compose MEMS cantilever more applicable in lower concentration bio-sensing. In such cantilever, the settling time of bio-molecule, which is mainly taken by the analyte molecule to settle down on the sensor surface, decreases and provides rapid detection of bio-molecules.

2. About COMSOL Multiphysics

COMSOL Multiphysics 4.3b, computer simulation has become an essential part of science and engineering. Digital analysis of components, in particular, is important when developing new products or optimizing designs. Today a broad spectrum of options for simulation is available; researchers use everything from basic programming languages to various high-level packages implementing advanced methods. When considering what makes software reliable, it’s helpful to remember the goal: you want a model that accurately depicts what happens in the real world. A computer simulation environment is simply a translation of real-world physical laws into their virtual form.

It would be ideal, then, to have a simulation environment that included the possibility to add any physical effect to your model. That is what COMSOL is all about. It’s a flexible platform that allows even novice users to model all relevant physical aspects of their designs. Advanced users can go deeper and use their knowledge to develop customized solutions, applicable to their unique circumstances. With this kind of all-inclusive modelling environment, COMSOL gives you the confidence to build the model you want with real world precision.

3. Working principle

In “in vivo analysis”, sensing unit need to be very sensitive. If the concentration of target analyte solution is small then it produces less pressure at the sensor surface. This less pressure generated by bio-molecular event is unable to sense by the conventional rectangular micro cantilever based sensor. So some new micro cantilever designs with better efficiency and sensitivity are proposed. For analyzing the deflection value, the surface area of all proposed designs is kept constant (5000μm²). The length and thickness of the proposed designs are also same as the conventional rectangular micro cantilever beam design.

4. Designing

Four models are designed here for comparative study.

1. Rectangular shaped micro cantilever beam.
2. Trapezoidal type micro cantilever beam.
3. Trapezoidal beam design with square step at fixed end.
4. Length wise symmetrical tree type micro cantilever beam design
Figure 1: Rectangular shaped micro cantilever beam

Figure 2: Trapezoidal type micro cantilever beam

Figure 3: Trapezoidal beam design with square step at fixed end

Figure 4: Length wise symmetrical tree type micro cantilever beam design
4.1 Applying Materials

For all the four models, Silicon (Si) is applied as the material for cantilever beam.

4.2 Applying Mesh

In the construction and computation of every material the size of the material plays a key role so we should apply mesh, which divides all the required analyzing part into small equal parts. So that the stress equally divides on every part, so the results will be clear and correct.

5. Results, Simulations and Discussions

A constant pressure of 19.2 Pa which is equivalent to the surface stress of 0.05 N/m is applied on the surface of four models discussed before. Now the micro cantilever beam that shows high deflection is considered as best for our applications.

![Figure 5: Displacement in Rectangular shaped micro cantilever beam](image)

![Figure 6: Displacement in Trapezoidal type micro cantilever beam](image)

![Figure 7: Displacement in Trapezoidal beam design with square step at fixed end](image)
5.1 Simulations

(i) The first simulation is by adding a layer of piezoelectric material (PZT-5H) under the micro cantilever beam. By this, we can know that which model is having better deflection for a constant pressure acting on the beam. This is because, the amount of charge produced in the Piezoelectric material is proportional to the deformation in the micro cantilever beam. Here only Rectangular and Trapezoidal beam with square step at fixed end designs are only considered because one is mostly used and the second design has best deformation results in the previous study.

(a) For Rectangular shaped beam

![Figure 9: Potential obtained for Rectangular shaped beam](image)

(b) For Trapezoidal beam with square step at fixed end design

![Figure 10: Potential obtained for Trapezoidal beam with square step at fixed end design](image)
(ii) Now the cantilever beam has to be designed with different materials like Si3N4, SiC for better simulation.

![Figure 11: Displacement in Si₃N₄ Material](image)

**Table 1: Displacement obtained in all the four models when Pressure is applied**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Type of construction</th>
<th>Total Displacement (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rectangular</td>
<td>1.0973x10⁻⁹</td>
</tr>
<tr>
<td>2</td>
<td>Trapezoidal</td>
<td>2.0097x10⁻⁹</td>
</tr>
<tr>
<td>3</td>
<td>Trapezoidal with square step at fixed end</td>
<td>2.2966x10⁻⁹</td>
</tr>
<tr>
<td>4</td>
<td>Symmetrical tree type</td>
<td>2.1085x10⁻⁹</td>
</tr>
</tbody>
</table>

![Figure 12: Displacement in SiC Material](image)

**Table 2: Potential obtained in selected two models**

<table>
<thead>
<tr>
<th>S. No</th>
<th>Type of construction</th>
<th>Total Potential obtained (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rectangular</td>
<td>2.507</td>
</tr>
<tr>
<td>2</td>
<td>Trapezoidal with square step at fixed end</td>
<td>3.6012</td>
</tr>
</tbody>
</table>
5.2 Discussions
From these obtained results and simulations it can be said that the trapezoidal beam with square step at fixed end design is highly sensitive and the best structure for cantilever beam. From this we can also state that Silicon is the best suited material for the micro cantilever beam. This is mainly used in "in vivo" applications.

6. Conclusion
Based on the simulation, a set of optimized design parameters are suggested. The corresponding performance parameters are also listed. Here the sensitivity is more for Trapezoidal beam design with square step at fixed end. The Silicon material is best suited in these types of biological applications.

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References